Environmental Tuning of Agriculture in the Netherlands

J. Van Bruchem[1], E.L. Lantinga[2], J. Overvest[3] and J.P.M. Jorink[3]
[1]Graduate School Wageningen Institute of Animal Sciences
[2]Graduate School C.T. de Wit Institute of Production Ecology
[3]Experimental Farm AP Minderhoudhoeve
Agriculture University (WAU) NL 6700 AH Wageningen, The Netherlands

Abstract

The agricultural sector of The Netherlands is very productive and profitable. However, the wastes of agriculture have developed problems of disposal Hence, the potential of EM as a method of utilizing wastes was evaluated to maintain productivity of agriculture while reducing pollution. The preliminary results suggest the benefits of EM along with organic matter. The potentials of the use of EM in the agriculture of Holland is presented on the basis of these results.

Introduction

Traditionally, agriculture products constitute a major part of the national trade balance of the Netherlands. However, over the last two decades public debate has started on the shadow sides of the current high external input (HEI) practices. In the Netherlands, the area of agricultural land approximates 2 million hectare. Therefore, to support the current livestock population, comprising about 5 million head of cattle, 15 million pigs and 80 million chickens/hens, a significant part of the feed is imported, particularly from over the Atlantic Ocean.

In Dutch agriculture, advanced production techniques have been adopted, in arable as well as livestock farming. Average production of the dairy cows is internationally almost unprecedented. Feed conversion ratio, i.e. feed over live weight gain, in pigs and poultry approximates 2.8 and 1.7, respectively. Layer hens approach the production of one egg per day.

Yet, public concern about current animal husbandry practices has gradually increased, Particularly with respect to intensive pig/poultry production, it is doubted whether housing and management systems are acceptable in terms of animal welfare. Public opinion is also not in favor of the use of hormones, e.g. oestradiol and BST. There is doubt whether modern reproduction techniques, e.g. MOET (multiple ovulation and embryo transfer), and genetic manipulation can be justified from an ethical point of view. Recent events with respect to animal health hazards, e.g. swine fever and BSE, have also triggered a discussion in this area. Should the current situation be improved through even larger scale closed semi-industrial aseptic production systems, or should the solution be sought in a more ecological context, in an integrated soil-plant-animal system in a microbiologically more balanced environment?

Apart from criticism about current animal husbandry practices, public concern exists about the environment aspects. In the Netherlands, agriculture as a whole is not environmentally sustainable. According to De Haan et al. (1993), it significantly contributes to the Dutch emission of greenhouse gases (~15 percent), acid rain (~50 percent) and groundwater pollution (~85 percent). The surplus of phosphate originates for ~55 percent from pig/poultry production. Dairy farming is responsible for ~60 percent of the nitrogen losses.

The high nutrient losses are associated with low nutrient use efficiencies at lower hierarchical levels, e.g. in the subsystems animal and soil (Van Keulen et al., 1996). Thus far solutions have primarily been sought in disciplinary research programmes. However, the high nutrient losses to the environment are primarily related to the huge external inputs of nutrients, which are beyond the carrying capacity of the regional agro-ecosystem and, hence, decrease internal nutrient use efficiency.

Despite their genetic merit, the efficiency with which animals convert energy and nutrients, i.e. nitrogen (N) and phosphorus (P), into animal product is rather low. The nutrient use efficiencies are, amongst others, related to the energy to nutrient ratios in products relative to those in the diet and the partitioning of the nutrients over maintenance and production. Hence, a major proportion of the

nutrients is dissipated in the air or excreted in faeces and urine.
Furthermore, it appears that technical developments when focused on a specific level/step of the process, e.g. nutrient dynamics at the level of the animal, aimed at more efficient ways of production, can lead to inefficiency on the longer term and at higher aggregation level. Therefore, there is an urgent need for integrating “lower level” disciplinary studies with studies of sustainable nutrient management at higher integration levels, to attain production systems in which the external inputs are better tuned to the outputs, and the nutrients in livestock manure, i.e. N and P. are re-utilized more efficiently. An excellent example of that approach is given by Aarts et al. (1992).
The notion sustainability implies the use of multiple criteria, each with its own target value, that cannot possibly be fully met at the same time. A sustainable production system should, (1) have no adverse effect on fragile regions elsewhere in the world and not jeopardize the needs of future generations, (2) be socially just and economically viable in the long term, (3) use non-renewable resources as efficient as possible, (4) be environmentally balanced, (5) produce sufficient and healthy products for human consumption at a fair price, and (6) take into account animal health and welfare. The one-sided pursuit of individualism has led to a breakdown of communities, so that cultures have come under pressure. Farms have become specialized and some components, once valued at the farm, have become wastes to be disposed off. Farming has also become more fossil-energy intensive, so also contributing to global warming. Hence, the effect of interventions should never be judged in isolation, but take into account trade off elsewhere in the production system, and not externalize problems/costs, neither on a spatial nor temporal scale.
This paper, primarily deals with nutrient emissions to the environment as one of the most acute problems to solve. An analysis is carried out, taking the nutrient flows in the soil-plant-animal production system as a point of departure. First, the nutrient balances are analyzed at national scale. Major production system as a point of departure. First, the nutrient balances are analyzed at national scale. Major sources of nutrient emissions to the environment are characterized. Options are identified to effectively tune agricultural production systems to the carrying capacity of the regional agro-ecosystem. Secondly, the layout of a mixed arable/dairy experimental farm, the “APMinderhoudhoeve” in Swifterbant, the Netherlands, is described. At this level of aggregation, various innovations are implemented and tested. Amongst others, the effects of the use of “effective micro-organisms” (EM) according to Parr et al. (1994), were investigated. Based on results, obtained at this level of aggregation, the impact of interventions is examined. A participatory approach has been adopted. The outcomes are extended to the field, and links are being established with groups of farmers in environmental cooperatives.

An analysis of nutrient balances at national scale

Recently, the Netherlands Council for Agricultural Research (NRLO) published a detailed analysis of the nutrient flows for nitrogen (N) and phosphorus (P) (Boons - Prins et al., 1996). For the agricultural sector, the balances for the Netherlands are presented in Table 1, specified for arable crop production and livestock production, On average, per hectare of agricultural land, the surpluses approximate 350 kg N and 45 kg P. Recent national legislation required reduction of the N and P surpluses towards the year 2008 to 180 kg N and 8.7 kg P per hectare, respectively.
Relative to other sectors, e.g. industry and transport, agriculture plays only a minor role in the production of greenhouse gases. The effects are mainly associated with the fossil energy component of feed production, e.g. processing of feed, transport and the production of fertilizer. Carbon dioxide production through livestock and human respiration is fully compensated by carbon dioxide fixation related to the production of feed/food biomass. Methane production, particularly by ruminants, is of a magnitude that does not justify major efforts for reduction (Crutzen, 1995).

Table 1. External Nutrient Inputs, Nutrient Outputs in Products, and Balances (106 $kg.yr^{-1}$), and Nutrient Use Efficiencies in Dutch Agriculture, on Two Million Hectares of Land.

	Cattle[3]	Pigs/Poultry	Crops	Total
Nitrogen				
Feed[1]	130	248	0	378
Fertilizer	303	17	124	444
Miscellaneous[2]	46	3	19	68
Product[4]	74	66	55	195
Balance[5]	405(58)	202(29)	88(13)	695
Efficiency[6]	0.15	0.25	0.38	0.22
Phosphorus				
Feed[1]	22	57	0	79
Fertilizer	26	1	11	38
Miscellaneous[2]	3	0	2	5
Product[4]	14	11	10	35
Balance[5]	37(43)	47(54)	3(3)	87
Efficiency[6]	0.28	0.19	0.77	0.29

[1]Improved roughage and concentrate feeds, including additives, minus export of concentrate feeds.
[2]Including deposition.
[3]Including cattle, sheep, goats and horses.
[4]Corrected for re-utilized by-products.
[5]Surplus: external inputs - output (relative proportions in brackets).
[6]Output/inputs: nutrient use efficiency (NUE).

In principle, various measures could be considered to reduce nutrient emissions to the environment, It has been suggested that agriculture in the Netherlands cannot possibly be tuned to the environment, unless production systems are drastically extensified. This conclusion is based on the fact that nutrient emissions to the environment have only slightly decreased over the last decade, despite all research and legislation efforts. According to recent figures from the Central Bureau for Statistics (CBS), over the period 1984-96, annual excretion of P by livestock decreased from l10 to 84 million kg, but increased for N from 622 to 641 million kg.

As appears from Table 1, livestock production is primarily responsible for the nutrient emissions to the environment. Cattle, i.e. dairy farming causes about 60 percent of the N surplus, and intensive livestock production about 55 percent of the P surplus. These are the most urgent environmental issues to tackle

Thus far, interventions have usually been based on research results at lower levels of aggregation. Reductionism implies breaking down the production system into its component parts, analyzing these in isolation, and then, assuming ceteris paribus, i.e. all other factors being equal, extrapolating towards behavior of the whole production system. This approach has led to a generation of new farming technologies and to production systems with a gradually decreasing nutrient use efficiency. Intensification of the production process, primarily governed by short-term economic incentives, has resulted in nutrient surplus per unit of land, as well as per unit of product, to levels unacceptable from an environmental point of view.

Based on the nutrient balances presented in Table 1, also considering the nutrients contained in homegrown feed, an estimate can be made of nutrient use efficiency at animal level (NUE-animal: nutrients in product over those in feed; including young stock) and apparent nutrient uptake efficiency from the soil (NUE-Soil: nutrients in homegrown feed over those in manure, fertilizer and miscellaneous inputs, including atmospheric deposition).

Table 2. Nutrient Use Efficiency at Animal Level (NUE-Animal) and Apparent Nutrient Uptake Efficiency from the Soil (NUE-soil).

	Nitrogen		Phosphorus	
	Cattle	**Pigs/Poultry**	**Cattle**	**Pigs/Poultry**
NUE-animal	0.16	0.30	0.21	0.26
NUE-soil	0.48	0.11	0.58	0.08

Because of the relatively high N concentration in roughage, NUE-N (animal) is relatively low in cattle. On the other hand, in cattle production systems, i.e. dairy farming systems, the major proportion of the feed is homegrown. Hence, NUE-Soil values are relatively high for cattle production, though still below 50 percent. Re-utilization of animal manure is extremely low in pig and poultry production. With production systems, more regionally based in terms of feed production, animal manure can be utilized much efficiently, and NUE-Soil values would improve considerably.

Instead of introducing costly end-of-pipe technologies and focusing on improving NUE-animal, problems could be more effectively solved, following a more integrated approach. The first step here is, identification of the various objectives of the different stakeholders in the rural development process. The next step is an analysis of the trade-off, especially in relation to scarce external inputs and environmental consequences. Level of production may be maintained while reducing external inputs, if the internal efficiency of nutrient use is improved. However, the solution is generally sought in improved technology, in controlling processes rather than designing systems which are more self-regulatory and self-supporting (Capra, 1996).

The effectiveness of possible interventions can be evaluated by sensitivity analysis of the soil-plant-animal-manure nutrient flows, for N and P in Dutch agriculture. Sensitivity coefficients denote the relative change in Y, i,e. (1) Production efficiency, and (2) nutrient losses, per unit change of X, i.e. nutrient use efficiency at animal level (NUE-animal), nutrient uptake efficiency from the soil (NUE-soil), and external concentrate and fertilizer inputs.

The sensitivity analysis shows that for N (Table 3), the efficiency of production, i.e. N in produce over N in external inputs, is determined in decreasing order by (1) apparent nitrogen uptake efficiency from the soil, (2) NUE at animal level, (3) fertilizer input (food/forage production), and (4) external input of concentrate feed. For P, the same order holds, except for external fertilizer and feed inputs. On the other hand, N/P surplus are most sensitive to fertilizer input (1/2), concentrate feed input (2/1) and apparent nutrient uptake efficiency from the soil (3/3). NUE at animal level (4/4) can be neglected in this respect. These results refer to the current level of nutrient throughput.

Table 3. Relative Effectiveness of Interventions with Respect to Production Efficiency and Nutrient Emissions to the Environment (Ranking in Brackets).

	Production efficiency		Nutrient surplus	
	N	**P**	**N**	**P**
Feed import	0.59(3)	0.77(2)	0.38(2)	0.60(1)
NUE-animal	0.61(2)	0.58(3)	0.17(4)	0.23(4)
Fertilizer	0.41(4)	0.24(4)	0.62(1)	0.40(2)
NUE-soil	0.94(1)	0.84(1)	0.26(3)	0.34(3)

Over the past four decades, nutrient use efficiency at national level has decreased, e.g. for dairy farming from 0.40 - 0.50 to less than 0.20 (Van Keulen et al,, 1996). The ranking of the sensitivity coefficients, as indicators for the effectiveness of interventions to reduce N surplus, explains why current efforts, e.g. government legislation and increasing milk production per cow, have not been really effective, Environmental tuning of agriculture under Dutch conditions should start with a gradual reduction in fertilizer input, particularly in dairy farming (Lantinga and Groot, 1996). The sensitivity analysis shows that no N use efficiency at animal level (NUE-animal), but rather apparent N uptake efficiency from the soil (NUE-soil) is the primary determinant of N use efficiency at the level of the farming system.

Research at farm level

With respect to livestock production, specialized livestock production systems and mixed farming systems can be distinguished (Sere and Steinfeld, 1996). On soil types that are not suitable for arable farming, e.g. peat and heavy clay, only specialized systems, e.g. dairy farming, can be practiced largely based on perennial grassland. Soil types suitable for arable farming allow development of mixed systems, with grass/clover ley, maize and whole-grain forage crops integrated in the crop rotation scheme. In mixed systems, natural resources, including by-products, are used most efficiently, and external inputs can more efficiently be adjusted to outputs. Thus, a high level of production can be maintained while nutrient losses to the environment are low.

On WAU experimental farm "APMinderhoudoeve" at Swifterbant (52^{o}35' northern latitude, 5^{o}40' eastern longitude) in the Flevopolder, an area reclaimed from the sea in the 1960es, next to a prototype ecological farm, a prototype mixed farm is designed, aiming at limited use of biocides and fertilizer. The livestock component on this includes dairy cattle and sheep. The farm aims at reducing the nutrient losses to environmentally acceptable levels, while maintaining the current high level of production.

Potentially, nutrient use efficiency of mixed farming can be higher than the sum of crop and livestock farming, through (1) use of crop by-products, e.g. straw, beet pulp and breweries grains, by the livestock, and (2) use of manure for crop production. The basal feed includes grass/clover, maize silage and whole-wheat silage. In the summer, N emissions to the environment are reduced through restricted grazing on the grass/clover ley during day-time and feeding maize and whole wheat silage at night. During winter, the basal dairy feed consists of (on a dry matter basis) 37 percent grass/clover silage, 30 percent maize/wheat silage, 15 percent beet pulp and 18 percent wheat/barley straw. For young stock of 1-2 yr and dry cattle the feed mix is composed of equal amount of grass/clover, maize/wheat silage and wheat/barley straw. The maize/wheat silage are used to compensate the N excess in the grass/clover mixture. Addition of straw is assumed to improve the quality of the slurry, by increasing its C/N ratio. This approach is thought to improve the type of microbial fermentation in the hindgut and the slurry, and to reduce ammonia emission from the stable and the formation of phytotoxic factors (Pare et al., 1997). Further, microbiological activity in the soil is presumed to be enhanced and organic matter content in the soil increased, on the longer run leading to more efficient nutrient uptake. Organic manure can also improve soil health. Lootsma (1997) showed that for fungal diseases in potatoes, controlling Rhizoctonia canker through enhancing of the mycophagous soil mesofauna.

The clay soil is ploughed before winter. Frost then improves soil structure in spring. Application of organic manure before winter is not desirable, because of the risk of nutrient losses during winter, a period with a distinct precipitation surplus, nor in spring to prevent structure damage. Therefore, slurry is only injected in the grass/clover lay. On an annual basis, in the grass/clover ley 100-200 kg N ha^{-1} are supposed to be immobilized in soil organic matter. The 2-yr period of grass/clover is followed by a 4-yr period of arable crops, including some maize/wheat fodder crops. An overall N use efficiency is estimated of 0.64, as aggregate of 0.23 for the livestock component, 0.56 for fodder production and apparently, 1.25 for arable production. These first outcomes are promising.

In view of the high N losses in dairy farming, thus far most attention has been paid to the N balance. In the current situation, the P balance for the arable crop component amounts to -6.8 kg.ha^{-1}, for the fodder crop and livestock component to 0.6 kg. ha^{-1}. The overall balance is negative: -6.2 kg. ha^{-1}. Hence, excluding fertilizer P would offer scope for solving part of the nutrient surpluses in intensive animal production. For example, a pig production unit could be introduced. This could most efficiently be done if part of the feed would be derived from own resources, e.g. some roughage feed for the sows and some beet pulp and breweries grains for fattening pigs. On an annual basis, a fattening pig excretes 14.5 kg N and 2.3 kg P (Van Eerdt, 1995). Hence, the mixed farm could accommodate about 2.5 fattening pig per hectare. The associated N excretion would be equivalent to -36 kg. ha^{-1}, equal to 60 percent of the current fertilizer input. According to such design, on average per hectare, still 25 kg N ha^{-1} would be available in spring, when soil temperatures are low, as a starting amount of fertilizer. essential for initial crop growth and development. A deep straw/composting set-up would possibly fit best. However, at national scale, such an integrated set-up could accommodate only about 25 percent of the current pig population.

In summary, a mixed integrated approach can solve a significant part of the environmental problems brought about by specialization, i.e. disintegration. Through integration, optimal use can be made of the classic positive interaction between crop and livestock production, with good quality organic manure as the primary driving force for soil fertility. It is a challenge to investigate what role this approach could play in controlling animal diseases. The revival of mixed farming offers a low external input, low cost option to reduce the environmental burden, and can offer agriculture a future with a production level than can suffice the needs of the steadily growing world population (Luyten, 1995).

Testing EM in an integrated context; Preliminary results

To test the impact of “effective micro-organisms (EM)” on the "APMinderhoudoeve" prototype farm, small-scale pilot experiments have been conducted. in onions, grass/clover pasture for day-time grazing in summer, and grass/clover lay for the production of winter feed, The experiments were carried out with two replicates only. Larger-scale experiments are needed, allowing a statistically more reliable evaluation.

Onions

Plots of 10 x 10m^2 were used with treatments, (1) chemical fertilizer only (NP), (2) chemical fertilizer and EM spray (NP+EM), and (3) EM compost (20 ton.ha^{-1}). The amount of nutrients applied and onion yields are presented in Table 4.

EM spray (4 times) in combination with chemical fertilizer tended to decrease onion yields. This can presumably be attributed to the low organic matter content in the young soil of approximately 4 percent only. With EM compost, onion yield showed a tendency to increase.

Grass/Clover Ley

In grass/clover ley, cut three times for ensiling and once for artificial drying, a similar experiment was executed. Fertilization and EM spraying were carried out at the onset of each growing period (Table 5).

Grass/Clover Pasture

In a grass/clover pasture used for grazing during day time, two strips were sprayed with EM and fertilized with EM slurry (30 m^3, ha^{-1}; 2 times). Cages, in total 8 EM and 8 control, covering each about 3 m^2 were placed to estimate grass/clover growth. Each month, the forage quantity was estimated, whereupon the cages were placed at another position. The results are presented in Table 6.

In the period September/October, cows showed some preference for grazing the EM strips. This could have led to a slight underestimated of grass/clover dry matter yields, since on the EM strips the cages may have been placed at positions with less dry matter in the standing grass/clover crop. This aspect deserves further attention in the next year.

In general terms, effective micro-organisms, if supplied with compost, tended to increased yields. Without additional organic matter, the effect of EM tended to be negative.

Table 4. Fertilizer Supply (kg.ha^{-1}) and the Effect of EM Spray and EM Compost on Yield (ton.ha^{-1}) in Onion (Relative Proportions in Brackets).

	NP	NP+EM	EM compost
Fertilizer N	**112/37**	**112/37**	**-/8**
Compost N	**-/-**	**-/-**	**112/29**
Yield <35mm	1.3(3)	1.6(3)	1.0(2)
Yield 35-60mm	38.3(77)	31.5(67)	43.5(84)
Yield >60mm	9.7(20)	13.9(30)	7.3(14)
Yield Total	49.3	47.0	51.0

Table 5. Fertilizer Supply (kg-ha^{-1}) and the Effect of EM Spray and EM Compost (21 ton.ha^{-1}) on Dry Matter Yield of Grass/Clover Ley.

	NP	NP+EM	EM compost
Fertilizer (N/P; kg ha^{-1})	80/45	80/45	60/15
Compost (N/P; kg ha^{-1})			120/30
Yield 1st cut (ton DM ha^{-1})	3.87	3.74	3.88
Fertilizer (N/P; kg ha^{-1})	60/--	60/--	40/--
Yield 2nd cut (ton DM ha^{-1})	4.27	3.88	4.39
Fertilizer (N/P; kg ha^{-1})	60/--	60/--	20/--
Yield 3rd cut (ton DM ha^{-1})	3.66	3.47	3.93
Fertilizer (N/P; kg ha^{-1})	40/--	40/--	--/--
Yield 4th cut (ton DM ha^{-1})	2.56	1.65	2.67
Fertilizer (N/P; kg ha^{-1})	240/45	240/45	240/45
Total yield (ton DM ha^{-1})	14.36	12.74	14.87

Table 6. Effect of EM Spray/Slurry on Yield (ton ha^{-1} DM) and (DM Content) of Grass/Clover Pasture.

	Control	EM spray/slurry
April-May	3.25 (21.5)	2.82 (22.7)
May-June	3.18 (18.7)	4.0 (20.3)
June-July	2.93 (14.4)	2.91 (14.4)
July-August	3.54 (18.1)	3.43 (17.7)
August-September	2.58 (16.1)	1.98[1)](16.7)
Total yield (ton DM ha^{-1})	15.5	15.1[1)]

[1)] Probably slightly underestimated because of preferential grazing of the EM strips.

Conclusions and priorities for future research

- Research focusing at improving the efficiency of subsystems in isolation and neglecting the needs/desire of all stakeholders involved, at different levels of hierarchy/integration and across different temporal/spatial scales, is bound to results in imbalance and increased risks, eventually unavoidably ending up in less efficiency.
- Nutrient use efficiencies in current high external input (HEI) animal production systems in the Netherlands are unacceptably low, while any justification for the high nutrient emissions to the environment is lacking. For the sake of a “healthier” agro-ecosystem and the perspectives for future generations, there is an urgent need to design and test production systems, that are geared towards higher internal nutrient use efficiencies, and limited use of external inputs, tuned to the agro-ecosystem’s carrying capacity.
- The key to solving multiple problems at the same time, e.g. (1) low nutrient use efficiencies, (2) poor quality of animal manure, (3) high disease risks, (4) resistance to antibiotics, and (5) improving human and animal welfare, should be sought in a biologically better functioning soil, the natural basis of agricultural production, with an improved buffering capacity for nutrients and water, enabling to maintain the high level of feed/food production while reducing external fertilizer inputs and nutrient emissions to the environment.
- It is anticipated that EM can play a role in alleviating the burden for the environment, the soil flora/fauna, the animal, and last but not least, farmers and consumers. Experiments carried out in isolation from their natural context cannot possibly yield any information on interrelations among sub-systems. Therefore, experiments must preferably be carried out in an integrated

context. A “top-down” approach is advocated starting with identification of constraints/ opportunities at “system” level, and priorities for “lower-level” disciplinary experiments. This in-depth research must preferably be carried our in the very same context, in order to arrive at the proper technical coefficients.

- In view of the adverse effect of EM on chemical fertilizer driven agriculture, special attention is needed for improving/safeguarding the soil’s organic matter status. Improving organic matter content of the soil will, in the longer run, also effectively contribute to solving the greenhouse problem.

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